The present invention relates to an adjustable magnet employable with an enclosed conduit to adjust or vary the magnetic field thereacross, said unit being particularly useful as an ion trap in conjunction with a cathode ray tube.

The necessity, in a cathode ray tube, of separating heavy ions from light ions so that only the electrons are caused to impinge upon the fluorescent screen end of the tube has long been realized. If the relatively heavy ions were permitted to accelerate and then strike the fluorescent screen, the bombardment effect would soon destroy the screen. It is accordingly standard practice in cathode ray tubes to employ, at a point between the electron gun and those deflecting elements which act in accordance with the signal impressed upon the tube, a trap for separating the ions from the electrons and permitting only the electrons to proceed further in the tube. Various means for separating the ions from the electrons have been employed, said means utilizing either electrostatic or magnetic forces or both. One of the most common means in use heretofore has been the employment of one or more electromagnets which have imparted thereto a constant bias resulting in a constant magnetic field across the path of the electrons and ions. Because of the variation in mass between these two types of particles, they are unequally deflected, the bias being so chosen as to permit the electrons to pass through an aperture while the ions impinge against and are stopped by a solid partition.

The use of electromagnets for this purpose involves certain practical difficulties, both as regards construction and expense. In the first place, separate circuit connections are required to the electromagnets, these involving considerable additional complexity in an already complex installation. In the second place, the idiosyncrasies of the electromagnet which forms a part of the ion trap is dependent upon the constancy of the current applied thereto and upon the security of the connections which it makes with the source of current. Should the current source vary, or should the connections, unknown to the user of the installation, become diselected in any way, the tube will not function correctly and it may be that, without any warning whatsoever, the fluorescent screen will be bombarded with ions so as to destroy its usefulness. In the third place, electromagnetic structures which are capable of use for this purpose are ordinarily rather bulky and rigid in construction and consequently must either be built with the cathode ray tube itself or secured in fixed positionthereon by relatively complex structural members cooperating with the unit in which the tube is positioned.

It has been proposed to avoid at least some of these objections to the use of electromagnets by employing permanent magnets since permanent magnets, particularly in the highly efficient forms in which they are commercially available today, are far less bulky and more dependable than electromagnets. However, in order to achieve efficient use of permanent magnets for this purpose, and further in order to make the installation somewhat adjustable so as to be conformable to tubes of various types and to the variations inherent in separate tubes of the same type, such complicated arrangements of permanent magnets have been employed as to prevent their use in practice.

It is the prime object of the present invention to devise a simple adjustable permanent magnet structure which may be readily manufactured at low cost and which may be adapted for use with cathode ray tubes of different types.

Another and more generalized object of the present invention is to devise a novel adjustable permanent magnet adapted to be used in conjunction with an enclosed conduit to adjust or vary the magnetic field thereacross.

It is a more specific object of the present invention to devise a magnetic ion trap employing a permanent magnet, said trap being readily removable from and receivable upon the neck of a cathode ray tube and being movable thereover to optimum position.

Another object of the present invention is to devise an adjustable permanent magnet structure including a linearly permanently magnetized body having a circular surface, said body being adjustably clamped in magnetic connection with a pair of opposite pole pieces.

To the accomplishment of the foregoing objects and such other objects as may hereinafter appear, the present invention relates to the adjustable permanent magnet structure as defined in the appended claims and as set forth in this specification, taken together with the accompanying drawings, in which:

Fig. 1 is a schematic view, partially in cross-section, of a typical cathode ray tube showing the adjustable permanent magnet structure of the present invention in position as an ion trap;

Fig. 2 is a front view of said permanent magnet structure;
Fig. 3 is a view similar to Fig. 2 but in cross-section; and Fig. 4 is a top cross-sectional view taken along the line 4-4 of Fig. 2.

Viewed broadly, the adjustable permanent magnet structure of the present invention comprises a pair of opposed pole pieces A formed of a magnetizable material such as soft iron and secured in opposed position by a connecting member B of non-magnetic material such as, for example, brass. A pair of magnet holding fingers C are structurally and magnetically connected to the pole pieces A and between them a permanent magnet D is articularly mounted so as to be movable to vary the effective magnetic field between the pole pieces A. A means E is provided to secure the magnet D in its desired position. As more specifically illustrated, the magnet D, while it has a linear magnetic orientation, as indicated by the arrows 2 in Fig. 4, is provided with a curved side surface 4 received between the correspondingly curved inner surfaces 5 of the magnet holding fingers C, the magnet D therefore being rotatable within said fingers C so as to vary the magnetic field between the pole pieces A.

When, as here specifically illustrated, the adjustable permanent magnet above described is adapted to be employed in conjunction with an enclosed conduit F so as to controllably vary the magnetic field thereacross, means G is provided for releasably and adjustably securing the pole pieces A to the exterior of said conduit.

Turning now more particularly to Fig. 1 in which the adjustable permanent magnet of the present invention is illustrated in use as an ion trap, a cathode ray tube 8 is shown having at one end a fluorescent screen 10 and at the other end an electron gun 12. The neck 15 of the tube is provided at its base 16 with prong connectors 19 so that the tube may be inserted into a conventional socket. A plurality of electromagnetic means, here schematically illustrated as coils 20 and 22, are provided to control the motion of the electron beam through the tube in accordance with the electrical signals fed to the coils 20 and 22, all as is conventional in the art.

The ion trap comprises, in combination with the permanent magnet structure of the present invention, a partition 24 having an aperture 22 therein. The electron gun 12 emits a stream composed of electrons and ions the path of which is indicated by the broken line 25. As this stream of electrons and ions passes between the pole pieces A, the magnetic field existant between said pole pieces acts to deflect the electrons and ions but, because of the different masses and speeds of said electrons and ions, they are unequally deflected, the ions moving along the path 30 so as to impinge upon the partition 24, their further progress through the tube 8 being thus interrupted, whereas the electrons travel along the path 32 so as to pass through the aperture 25 and proceed to the fluorescent screen 10.

It is to be understood that the showing in Fig. 1 of the elements of the cathode ray tube is schematic only and many of the conventional elements thereof, such as accelerating electrodes and the like, are omitted because they form no part of the present invention and are not necessary to the proper understanding thereof.

The adjustable permanent magnet of the present invention may be adapted for use with cathode ray tubes of varying types or may compensate either for progressive variations in the operating characteristics of a given tube or for the unavoidable constructive variations between tubes of the same type, either by adjusting the magnitude or field between the pole pieces A or by varying the position of the magnet structure along the neck 14 of the tube 9, or both. These variations are accomplished by virtue of the artfully and efficient construction of the adjustable permanent magnet unit as will now be more specifically described.

The pole pieces A are shaped so as to partially encompass the conduit F in connection with which they are to be used. Since the neck 14 of cathode ray tubes are generally circular in shape, the upper portions 34 of the pole pieces A are appropriately curved and the brass or other non-magnetic connecting member B, which may be secured to the curved portions 35 of the pole pieces A either by means of rivets 33 or by any other convenient means, is correspondingly curved. The connecting member B therefore serves the dual function of maintaining the pole pieces A in a fixed opposed relation one to the other and at the same time assists in the at least partial encompassing of the enclosed conduit F.

Preferably integrally formed with and projecting upwardly from the curved portions 34 of the pole pieces A are the magnet holding fingers C which are also of magnetic material such as soft iron. Indented portions 38 are preferably formed someplace along the length of the fingers C so as to hold the circular magnet D which is received between the fingers C in spaced position above the connecting member B.

As specifically illustrated, the magnet D takes the form of a disc of permanent magnetic material such as Alnico having flat upper and lower surfaces 45 and 47 and a curved side surface 44. The interior surface 6 of the magnet holding fingers C are given a curvature corresponding to that of the side surface 4 of the magnet D so that the magnet D fits relatively snugly therebetween. Its bottom surface 42 being supported on the indent portions 35, the magnet D being rotatable in the axial position. Since it has a linear magnetic orientation as indicated by the arrows 2 in Fig. 4, it will be apparent that if the magnet D is positioned between the fingers C so that its line of magnetic orientation 2 passes directly between the fingers C, the magnetic field across the pole pieces will be at a maximum. If the magnet D be rotated 90° from that position, so that its line of magnetic orientation 2 is perpendicular to a line between the centers of the fingers C, the magnetic field across the pole pieces A will disappear. If the magnet D take up a position intermediate between the two previously described extremes positions, one of such intermediate positions being illustrated in Fig. 4, the magnetic field across the pole pieces A will have an intermediate value. If the magnet D be rotated more than 90° from its initial described position, not only will the magnitude of the field between the pole pieces A be different, but its direction will also be reversed.

The means E for securing the magnet D in any desired adjusted position comprises a screw 44 passing through an aperture 46 in one of the fingers C above the magnet D and threadedly received in an aperture 48 in the opposite finger C. It will be apparent that as the screw 44 is rotated in an appropriate direction, the fingers C will be drawn toward one another and conse-
quently the magnet D will be firmly and fixedly clamped in position. If it be desired at any time to vary the magnetic field between the pole pieces A, it is necessary only to let up on the screw 44, thus permitting the fingers C to move apart and release the magnet D for adjustment, and then, after the magnet D has been moved to its new desired position, it may then be again clamped in place.

The structure as thus far described, while it is receivable over and partially encompasses the end magnetic field of F, is not readily a securable thereto in desired position. Consequently, the means G for securing the structure to the exterior of the conduit F with which the unit is to be used, this member, like the member B, being composed of a non-magnetic material such as brass so as not to short-circuit the magnetic field between the pole pieces A. The depending end of one of the pole pieces A is provided with an aperture 52 and an end 54 of the member 50 is received therein and bent over so that the member 50 is pivotally attached to that pole piece A. As illustrated, the hooked end portion 54 of the member 50 is only bent around to a limited degree so that the member 50 may also be detached from the pole piece A as desired. The lower end of the opposite pole piece A is provided with a projecting lip 55 having an aperture 58 there-through and the second connecting member 55 is provided with a corresponding projecting portion 56, provided with a threaded aperture 62, the projecting portion 56 being adapted to underlie the lip 55 so that the apertures 52 and 58 may be brought into registration. A screw 64 passes through the aperture 58 and is threadedly received within the aperture 52 so that rotation of the screw will cause the lips 55 and 59 to approach and recede from one another depending upon the amount and direction of rotation of the screw 64. In order to provide a cushioning action and to prevent the application of undue strain upon the conduit F, resilient pads 66 and 68 are approximately in an appropriate manner to the inner curved surfaces of the connecting members B and 50.

The functioning and manner of use of the adjustable permanent magnet structure of the present invention will in the main be apparent from the above description. The magnitude and direction of magnetic field between the pole pieces A may be controlled by the appropriate positioning of the line of magnetic orientation 2 of the magnet D with respect to the magnet-holding fingers C between which the magnet may be secured, the adjustment being achieved in the embodiment illustrated by rotating the magnetic D as it is held between the fingers C. By manipulation of the screw 44, the magnet may be either released for adjustment or firmly clamped in adjusted position. Such an adjustable permanent magnet holding structure may be used in association with a variety of apparatus from the specific application as an ion trap here illustrated. However, when the structure is to be employed in conjunction with an enclosed conduit so as to adjust or vary the magnetic field thereacross, the second connecting member 50 may be provided with the hooked end 54 of the member 50 through the aperture 52 in the end of the pole piece A. The unit may then be placed in position around the conduit F with the connecting member B on one side thereof, the connecting member 50 on the opposite side thereof, and the pole pieces A extending between the connecting members B and 50 on opposite sides of the conduit F and, by manipulation of the screw 64, the structure may be clamped in fixed position. If it be desired for any reason to vary the position of the magnet structure on the conduit F, either to move it longitudinally thereof or rotatively thereon, it is necessary only to loosen up on the screw 64, slide the permanent magnet unit to its desired position, and then clamp it in that position by tightening up on the screw 64.

It has been found experimentally that with the unit of the present invention and quite apart from the use of any other magnetic or electrostatic deflecting device, effective ion-electron separation can be achieved in cathode ray tubes as currently manufactured. By varying the strength of the magnetic field across the pole pieces A and by adjusting the position of the magnet unit with relation to the position of the cathode ray tube 8, a single standardized magnet structure can be employed with cathode ray tubes of varying types, the same standardized structure also being utilized to compensate for the normal manufacturing variations in the characteristics of tubes of the same type. Not only is such a standardized structure advantageous because it is considerably less expensive to manufacture than comparable electromagnetic units, but its use also involves no additional circuit connections and its flexibility of adaptation and ability to be readily adjusted either to compensate for changes in operating characteristics of tubes during their life or to be used with tubes of varying types makes it an exceedingly valuable magnetic construction.

While only one embodiment of magnet structure is here illustrated, it will be apparent that many variations may be made therein. Thus, the manner of securing the pole pieces A to one another, the shape thereof, the manner of connecting the magnet holding fingers C to the pole pieces A, the manner of securing the member D in adjusted position, and the manner of securing the entire unit on the enclosed conduit F, to mention but a few details, may all be varied within wide degrees without departing from the spirit of the invention as defined in the following claims.

1. An adjustable permanent magnet comprising a pair of opposed pole pieces of magnetic material, a connecting member of non-magnetic material secured to said pole pieces for holding them spaced one from the other, a pair of opposed magnet holding fingers of magnetic material projecting from said pole pieces, said fingers extending toward one another but not meeting so as to define an open-sided space, a self-sustaining permanent magnet body articulatedly mounted between said magnet holding fingers in said open-sided space and movable in the magnetic field between said pole pieces, and means active between said fingers for securing said magnet in a desired position.

2. An adjustable permanent magnet comprising a pair of opposed pole pieces of magnetic material, a connecting member of non-magnetic material secured to said pole pieces for holding them spaced one from the other, a pair of opposed magnet holding fingers of magnetic mate-
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a magnet holding portion magnetically and structurally connected to said pole pieces, a permanent magnet articulately mounted in said magnet holding portion and movable to vary the magnetic field between said pole pieces, and means for securing said magnet in a desired position.

7. An adjustable permanent magnet adapted to be used in conjunction with an enclosed conduit to adjust the magnetic field thereacross comprising a pair of arms of magnetizable material each capable of encompassing opposite portions of the exterior of said conduit, said arms defining opposed pole pieces, a pair of connecting members of non-magnetizable material each secured between said arms at opposite extremities thereof, one of said connecting members being adjustably secured to said arms so as to permit the exterior of said conduit to be releasably and adjustably clamped to said conduit, and means for securing said connecting members in a desired position.

8. An adjustable permanent magnet adapted to be used in conjunction with an enclosed conduit to adjust the magnetic field thereacross comprising a pair of arms of magnetizable material each capable of encompassing opposite portions of the exterior of said conduit, said arms defining opposed pole pieces, a pair of connecting members of non-magnetizable material each secured between said arms at opposite extremities thereof, a permanent magnet articulately mounted in said magnet holding portion and movable to vary the magnetic field between said pole pieces, and means for securing said magnet in a desired position.

9. In the adjustable permanent magnet of claim 8, resilient pads on the interior surfaces of said connecting members.

10. The adjustable permanent magnet of claim 8, in which the opposite interior surfaces of said magnet holding fingers are arcuate in shape, a circular permanent magnet having linear magnetic orientation being rotatably retained between said interior surfaces, rotation of said magnet varying the effective magnetic field between said pole pieces.

11. The adjustable permanent magnet of claim 10, in which the means for securing the magnet in a desired position comprises a permanent magnet having linear magnetic orientation being rotatably retained between said interior surfaces, rotation of said magnet varying the effective magnetic field between said pole pieces.

12. A charged particle deflecting unit adapted to be used in conjunction with an enclosed particle conduit comprising a pair of arms of magnetizable material, one positionable on each side of said conduit, said arms defining opposed pole pieces, a pair of connecting members of non-magnetizable material each secured between said arms at opposite extremities thereof, one of said connecting members being adjustably secured to said arms so as to permit said arms to be releasably and adjustably clamped to the exterior of said conduit, a pair of opposed magnet holding fingers of magnetizable material each connected to one of said arms.
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sought arms and projecting therefrom, a permanent magnet retained between said fingers so as to be movable to vary the magnetic field between said pole pieces, and means for securing said magnet in a desired position.

13. A charged particle deflecting unit adapted to be used in conjunction with an enclosed particle conduit comprising a pair of arms of magnetizable material, each capable of encompassing opposed portions of the exterior of said conduit, said arms defining opposed pole pieces, a pair of connecting members of non-magnetizable material each secured between said arms at opposite extremities thereof, one of said connecting members being adjustably secured to said arms so as to permit said arms to be releasably and adjustably clamped to the exterior of said conduit, a pair of opposed magnet holding fingers of magnetizable material each connected to one of said arms and projecting therefrom adjacent the non-adjustably secured connecting member, a permanent magnet retained between said fingers so as to be movable to vary the magnetic field between said pole pieces, and means for securing said magnet in a desired position.

14. A charged particle deflecting unit adapted to be used in conjunction with an enclosed particle conduit comprising a pair of arms of magnetizable material, each capable of encompassing opposed portions of the exterior of said conduit, said arms defining opposed pole pieces, a pair of connecting members of non-magnetizable material each secured between said arms at opposite extremities thereof, one of said connecting members being adjustably secured to said arms so as to permit the exterior of said conduit to be releasably and adjustably clamped between said connecting members, a pair of opposed magnet holding fingers of magnetizable material each connected to one of said arms and projecting therefrom adjacent the non-adjustably secured connecting member, a permanent magnet retained between said fingers so as to be movable to vary the magnetic field between said pole pieces, and means for securing said magnet in a desired position.

15. A charged particle deflecting unit adapted to be used in conjunction with an enclosed particle conduit comprising a pair of arms of magnetizable material, each capable of encompassing opposed portions of the exterior of said conduit, said arms defining opposed pole pieces, a pair of connecting members of non-magnetizable material each secured between said arms at opposite extremities thereof, one of said connecting members being pivotally fastened to one of said arms and releasably fastened to the other of said arms so as to permit the exterior of said conduit to be releasably and adjustably clamped between said connecting members, a pair of opposed magnet holding fingers of magnetizable material each connected to one of said arms and projecting therefrom adjacent the non-pivotally fastened connecting member, a permanent magnet retained between said fingers so as to be movable to vary the magnetic field between said pole pieces, and means for securing said magnet in a desired position.

16. In the charged particle deflecting unit of claim 15, resilient pads on the interior surfaces of said connecting members.

17. A charged particle deflecting unit adapted to be used in conjunction with an enclosed particle conduit comprising a pair of opposed pole pieces of magnetizable material shaped to partially encompass a portion of the exterior of said conduit, a first connecting member of non-magnetizable material rigidly connected to said pole pieces at one extremity thereof, a pair of opposed magnet holding fingers of magnetizable material connected to said pole pieces and projecting therefrom at said extremity, a permanent magnet retained between said fingers so as to be movable to vary the magnetic field between said pole pieces, means for securing said magnet in a desired position, and a second connecting member of non-magnetizable material adjustably connected to said pole pieces at their other extremity, whereby said unit may be secured to the exterior of said conduit.

18. A charged particle deflecting unit adapted to be used in conjunction with an enclosed particle conduit comprising a pair of opposed pole pieces of magnetizable material shaped to partially encompass a portion of the exterior of said conduit, a first connecting member of non-magnetizable material rigidly connected to said pole pieces at one extremity thereof, a pair of opposed magnet holding fingers of magnetizable material connected to said pole pieces and projecting therefrom at said extremity, a permanent magnet retained between said fingers so as to be movable to vary the magnetic field between said pole pieces, means for securing said magnet in a desired position, and a second connecting member of non-magnetizable material pivotally connected to one of said pole pieces and releasably connected to the other of said pole pieces at their other extremity, whereby said unit may be secured to the exterior of said conduit.

19. The charged particle deflecting unit of claim 18, in which the opposite interior surfaces of said magnet holding fingers are arcuate in shape, a circular permanent magnet having linear magnetic orientation being rotatably retained between said interior surfaces, rotation of said magnet varying the effective magnetic field between said pole pieces.

20. The charged particle deflecting unit of claim 19, in which the means for securing the magnet in its desired position comprises an adjustable connection between said fingers for moving them toward and away from one another.

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